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इलेक्ट्रॉनिकी एवं विद्युतीय मदों के लिए बेसिक पर्यावरण परीक्षण कार्यविधियाँ

भाग 7 संघटट परीक्षण

अनुभाग 1 प्रघात (परीक्षण Ea)

(पहला पुनरीक्षण)

Indian Standard

BASIC ENVIRONMENTAL TESTING PROCEDURES FOR ELECTRONIC AND ELECTRICAL ITEMS

PART 7 IMPACT TEST

Section 1 Shock (Test Ea)

(First Revision)

ICS 19.040

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MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

August 2006

Price Group 10

Environmental Testing Procedures Sectional Committee, LTD 02

NATIONAL FOREWORD

This Indian Standard (Part 7/Sec 1) (First Revision) which is identical with IEC 60068-2-27 (1987) 'Basic environmental testing procedures — Part 2 : Tests — Test Ea and guidance: Shock' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Environmental Testing Procedures Sectional Committee and approval of the Electronics and Information Technology Division Council.

This standard was originally published in 1979 and was identical with IEC 60068-2-27 (1972) and has now been revised to align it with the latest IEC Publication.

The text of the IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their places are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60068-1 (1982) Basic environmental testing procedures — Part 1 : General and guidance	IS 9000 (Part 1) : 1988 Basic environmental testing procedures for electronic and electrical items: Part 1 General (*first revision*)	Technically Equivalent
IEC 60068-2-29 (1986) Basic environmental testing procedures — Part 2 : Tests — Test Eb and guidance : Bump	IS 9000 (Part 7) : 1979 Basic environmental testing procedures for electronic and electrical items: Part 7 Impact test	do
IEC 60068-2-31 (1969) Basic environmental testing procedures — Part 2 : Tests — Test Ec : Drop and topple, primarily and equipment-type specimens		
IEC 60068-2-32 (1975) Basic environmental testing procedures — Part 2 : Tests — Test Ed : Free fall		
IEC 60068-2-47 (1982) Basic environmental testing procedures — Part 2 : Tests — Mounting of components, equipment and other articles for dynamic tests including shock (Ea), bump (Eb), vibration (Fc and Fd) and steady-state acceleration (Ga) and guidance	IS 9001 (Part 12) : 1979 Guidance for environmental testing: Part 12 Mounting of electric and electrical items for dynamic tests	do

(*Continued on third cover*)

IS 9000 (Part 7/Sec 1) : 2006
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Indian Standard

BASIC ENVIRONMENTAL TESTING PROCEDURES FOR ELECTRONIC AND ELECTRICAL ITEMS

PART 7 IMPACT TEST

Section 1 Shock (Test Ea)

(First Revision)

INTRODUCTION

This test is applicable to components, equipments and other electrotechnical products, hereinafter referred to as "specimens", which, during transportation or in use, may be subjected to conditions involving relatively infrequent non-repetitive shocks. The shock test may also be used as a means of establishing the satisfactory design of a specimen in so far as its structural integrity is concerned and as a means of quality control. It consists basically of subjecting a specimen to non-repetitive shocks of standard pulse shapes with specified peak acceleration and duration.

Specification writers will find in Clause 11 a list of details to be considered for inclusion in specifications and in Appendix A the necessary guidance.

1. Object

To provide a standard procedure for determining the ability of a specimen to withstand specified severities of shock.

2. General description

This standard is written in terms of prescribed pulse shapes. Guidance for the selection and application of these pulses is given in Appendix A and the characteristics of the different pulse shapes are discussed in Appendix B. Three types of pulse, namely the half-sine pulse, the final-peak saw-tooth pulse and the trapezoidal pulse are included in this standard. The choice of pulse shape depends on a number of factors, and the difficulties inherent in making such a choice preclude a preferred order being given in this standard (see Clause A3).

The purpose of the test is to reveal mechanical weakness and/or degradation in specified performance and to use this information, in conjunction with the relevant specification, to decide whether a specimen is acceptable or not. It may also be used, in some cases, to determine the structural integrity of specimens or as a means of quality control (see Clause A2).

This test is primarily intended for unpackaged specimens and for items in their transport case when the latter may be considered as part of the specimen itself.

The shocks are not intended to reproduce those encountered in practice. Wherever possible, the test severity and the shape of the shock pulse applied to the specimen should be such as to reproduce the effects of the actual transport or operational environment to which the specimen will be subjected, or to satisfy the design requirements if the object of the test is to assess structural integrity (see Clauses A2 and A4).

For the purpose of this test the specimen is always fastened to the fixture or the table of the shock-testing machine during conditioning.

In order to facilitate the use of this standard, references are given in the main part where the reader is invited to refer to Appendix A and also the clause numbers in the main part are referred to in Appendix A.

This standard is to be used in conjunction with IEC Publication 68-1: Basic Environmental Testing Procedures, Part 1: General and Guidance.

3. Definitions

The terms used are generally defined in ISO Standard 2041 or IEC Publication 68-1.

The following additional terms and definitions are also applicable for the purposes of this standard.

3.1 *Fixing point*

Part of the specimen in contact with the fixture or the table of the shock testing machine and which is normally used to fasten the specimen in service.

3.2 *Check point*

Fixing point nearest to the centre of the table surface of the shock testing machine, unless there is a fixing point having a more rigid connection to the table, in which case this latter point shall be used.

Note. — This definition applies as there is only one nominated check point. Other standards in IEC Publication 68-2 contain definitions of "check point" applicable where provision is made for the control of the test by nomination of more than one check point.

3.3 *Shock severity*

Combination of the peak acceleration and the duration of the nominal pulse.

3.4 *Velocity change*

Absolute value of the sudden change of speed resulting from the application of the specified acceleration.

Note. — The change is normally considered sudden if it takes place in a time that is short compared with the fundamental period of concern.

3.5 g_n

Standard acceleration due to the earth's gravity, which itself varies with altitude and geographical latitude.

Note. — For the purposes of this standard, the value of g_n is rounded up to the nearest unity, that is 10 m/s².

4. Description of test apparatus

4.1 *Required characteristics*

When the shock testing machine and/or fixture are loaded with the specimen, the shock applied at the check point shall consist of a pulse approximating to one of the nominal acceleration against time curves given by the broken lines in Figures 1, 2 and 3, pages 17 to 19.

4.1.1 *Basic pulse shapes*

The true value of the actual pulse shall be within the limits of tolerance shown by the solid lines in the relevant figure.

Note. — Where it is not practicable to achieve a pulse shape falling within the specified tolerance, the relevant specification should state the alternative procedure to be applied (see Clause A5).

The prescribed pulse shapes are given below. The order in which they are given does not indicate a preference.

Final-peak saw-tooth: asymmetrical triangle with short fall time, as shown in Figure 1.

Half-sine: one half-cycle of a sine wave, as shown in Figure 2.

Trapezoidal: symmetrical trapezoid with short rise and fall times, as shown in Figure 3.

4.1.2 *Velocity change tolerances*

For all pulse shapes, the actual velocity change shall be within ±15% of the value corresponding to the nominal pulse.

Where the velocity change is determined by integration of the actual pulse, this shall be done from $0.4D$ before the pulse to $0.1D$ beyond the pulse, where D is the duration of the nominal pulse.

Note. — If the velocity change tolerance cannot be achieved without the use of elaborate facilities, the relevant specification should state the alternative procedure to be adopted (see Clauses A5 and A6).

4.1.3 *Transverse motion*

The positive or negative peak acceleration at the check point, perpendicular to the intended shock direction, shall not exceed 30% of the value of the peak acceleration of the nominal pulse in the intended direction, when determined with a measuring system in accordance with Sub-clause 4.2 (see Clause A5).

Note. — If the transverse motion tolerance cannot be achieved, the relevant specification should state the alternative procedure to be adopted (see Clause A5).

4.2 *Measuring system*

The characteristics of the measuring system shall be such that it can be determined that the true value of the actual pulse as measured in the intended direction at the check point is within the tolerances required by the figures referenced in Sub-clause 4.1.1.

The frequency response of the overall measuring system, which includes the accelerometer, can have a significant effect on the accuracy and shall be within the limits shown in Figure 4, page 20 (see Clause A5).

4.3 *Mounting*

The specimen shall be fastened to the shock testing machine table or fixture by its normal mounting means during conditioning. Mounting requirements are specified in I E C Publication 68-2-47.

5. Severities

The relevant specification shall prescribe both the pulse shape and the shock severity. One of the pulse shapes given in Sub-clause 4.1.1 and a severity given in Table I shall be chosen.

Unless otherwise specified, one of the combinations shown on the same line in Table I shall be used. The preferred combinations are underlined. The corresponding velocity changes are also given (see Clause A4).

Note. — If the effects of the known environment on the specimen cannot be reproduced by severities given here the relevant specification may prescribe an appropriate severity using one of the standard pulse shapes, shown in Figures 1, 2 and 3 (see Clause A4).

TABLE I

Acceleration and duration of the pulse

Peak acceleration		Corresponding duration of the nominal pulse	Corresponding velocity change (ΔV)		
			Half-sine	Final-peak saw-tooth	Trapezoidal
(A)		(D)	$\Delta V = \frac{2}{\pi} AD \times 10^{-3}$	$\Delta V = 0.5\ AD \times 10^{-3}$	$\Delta V = 0.9\ AD \times 10^{-3}$
g_n	(Equivalent m/s²)	ms	m/s	m/s	m/s
5	(50)	30	1.0	—	—
15	(150)	11	1.0	0.8	1.5
30	**(300)**	**18**	**3.4**	**2.6**	**4.8**
30	(300)	11	2.1	1.6	2.9
30	(300)	6	1.1	0.9	1.6
50	**(500)**	**11**	**3.4**	**2.7**	**4.9**
50	(500)	3	0.9	0.7	1.3
100	(1 000)	11	6.9	5.4	9.7
100	**(1 000)**	**6**	**3.7**	**2.9**	**5.3**
200	(2 000)	6	7.5	5.9	10.6
200	(2 000)	3	3.7	2.9	5.3
500	**(5 000)**	**1**	**3.1**	—	—
1 000	(10 000)	1	6.2	—	—
1 500	**(15 000)**	**0.5**	**4.7**	—	—
3 000	(30 000)	0.2	3.7	—	—

6. Pre-conditioning

The relevant specification may call for pre-conditioning.

7. Initial measurements

The specimen shall be submitted to the visual, dimensional and functional checks prescribed by the relevant specification.

8. Conditioning

8.1 *Application of shocks*

Unless otherwise prescribed by the relevant specification, three successive shocks shall be applied in each direction of three mutually perpendicular axes of the specimen, that is a total of 18 shocks.

When testing a number of identical specimens they may be so oriented that the shocks are applied simultaneously along the axes and in the directions referred to above (see Clause A7).

8.2 *Operating mode and functional monitoring*

The relevant specification shall state whether the specimen shall:

a) operate during shock and if any functional monitoring is required;

and/or

b) survive the conditions of shock.

For both cases the relevant specification shall provide the criteria upon which the acceptance or rejection of the specimen is to be based.

9. Recovery

The relevant specification may call for recovery.

10. Final measurements

The specimen shall be submitted to the visual, dimensional and functional checks prescribed by the relevant specification.

The relevant specification shall provide the criteria upon which the acceptance or rejection of the specimen is to be based.

11. Information to be given in the relevant specification

When this test is included in a relevant specification, the following details shall be given as far as they are applicable.

	Clause, sub-clause
a) Pulse shape (Clause A3)	4.1.1
b) Tolerances, special cases (Clause A5)	4.1.1
c) Velocity change, special cases (Clause A6)	4.1.2
d) Transverse motion, special cases	4.1.3
e) Method of mounting	4.3
f) Severity (Clause A4)	5
g) Pre-conditioning	6
h) Initial measurements	7
i) Directions and number of shocks in special cases only (Clause A7)	8.1
j) Operating modes and functional monitoring	8.2
k) Acceptance and rejection criteria	8.2, 10
l) Recovery	9
m) Final measurements	10
n) High frequency cut-off (Clause A5)	Figure 4, page 20

APPENDIX A

GUIDANCE

A1. Introduction

The test provides a method by which effects on a specimen comparable with those likely to be experienced in practice in the environment to which the specimen will be subjected during either transportation or operation can be reproduced in the test laboratory. The basic intention is not necessarily to reproduce the real environment.

The parameters given are standardized and suitable tolerances are chosen in order to obtain similar results when a test is carried out at different locations by different people. The standardization of values also enables components to be grouped into categories corresponding to their ability to withstand certain severities given in this standard.

In order to facilitate the use of this appendix, the related clause numbers of the main part are referred to herein.

A2. Applicability of test

Many specimens are liable to be subjected to shock during use, handling and transportation. These shocks will be at widely varying levels and will also be of a complex nature. The shock test provides a convenient method for establishing the ability of a specimen to withstand these conditions of non-repetitive shocks. For repetitive shocks, Test Eb and Guidance: Bump (IEC Publication 68-2-29) is considered to be more appropriate (see Appendix C).

The shock test is also suitable for structural integrity tests on component type specimens for qualification and/or for quality control purposes. It is normal under these circumstances to utilize high acceleration shocks with the main purpose of applying a known force to the internal structure of a specimen, particularly those containing cavities (see Clause 2).

The specification writer intending to call up this test should refer to Clause 11 "Information to be given in the relevant specification", in order to ensure that all such information is provided.

A3. Pulse shapes (Clause 2)

Three shapes of shock pulse which are in general use are given in this standard and for test purposes any of these may be used (see also Sub-clause 4.1.1 and Table I).

The half-sine pulse has application when reproducing the effects of a shock resulting from impact with, or retardation by, a linear rate system, for example impact involving a resilient structure.

The trapezoidal pulse produces a higher response over a wider frequency spectrum than the half-sine pulse. It should be applied when the purpose of the test is to reproduce the effects of shock environments such as the 'explosive bolt' phase of a space probe/satellite launch.

Note. — The half-sine pulse shape is the most generally applicable. The trapezoidal pulse shape is not primarily intended for component type specimens.

The final-peak saw-tooth pulse has a more uniform response spectrum than the half-sine and trapezoidal pulse shapes.

Information on the shock spectra associated with these pulses is given in Appendix B.

Where the shock spectrum of the operational/transportation environment is known, reference should be made to Figures 5, 6 and 7, pages 21 to 23 in order to select the shape of the pulse most nearly conforming to it. Where the shock response spectrum of the operational/transportation environment is not known, reference should be made to Table II which lists the test severities and pulse shapes applicable to specimens intended for various classes of transportation and operational use.

For packaged items, the shocks encountered during handling and transportation are often of a simple nature which makes it possible to use a half-sine pulse derived from the observed velocity change.

A4. **Test severity** (Clauses 2 and 5)

Wherever possible, the test severity and the shape of the shock pulse applied to the specimen should be related to the environment to which the specimen will be subjected, during either transportation or operation, or to the design requirements if the object of the test is to assess structural integrity.

The transportation environment is frequently more severe than the operational environment and in these circumstances the test severity chosen may need to be related to the former. However, although the specimen may only need to survive the transportation environment it will normally be required to function during the operational environment, where appropriate. Therefore, it may be necessary to carry out shock tests under both conditions, with measurements of certain parameters after the "transportation environment" test and functional checks during the "operational environment" test.

When determining the test severity to be applied, consideration should be given to the possible need to allow an adequate safety margin between it and the conditions of the real environment.

TABLE II

Examples of pulse shapes and test severities typically employed for various applications

This table lists severities which are not mandatory but which are typical of the various applications. It should be remembered that there will be instances where the real severities differ from those shown in the table.

Severity			Pulse shape	Component use	Equipment use
Peak acceleration		Duration			
g_n	(Equivalent m/s²)	ms			
15	(150)	11	Final-peak saw-tooth Half-sine Trapezoidal		General test for robustness, handling and transport Land based items permanently installed or only transported by road, rail or air in secured shock-resistant packages
30	(300)	18	Final-peak saw-tooth Half-sine Trapezoidal		Structural integrity of mountings Installed or transported in a secured position on normal road or rail vehicles or in transport aircraft
50	(500)	11	Final-peak saw-tooth Half-sine Trapezoidal *	Items in secured packages transported by wheeled vehicles (normal road or rail) subsonic or supersonic transport aircraft, merchant ships or light marine craft Items mounted in equipment transported by, or installed in, wheeled vehicles (normal road or rail) subsonic or supersonic transport aircraft, merchant ships or light marine craft Items for installation in heavy industrial equipment	Items installed or transported in a secured position in full cross-country vehicles Items carried loose in normal road or rail vehicles for long periods Items used in industrial areas and subjected to shock from mechanical handling equipment, for example: dock cranes, fork-lift trucks

* Not primarily intended for component type specimens.

(Table continued on page 9

TABLE II *(continued)*

Severity			Pulse shape	Component use	Equipment use
Peak acceleration		Duration			
g_n	(Equivalent m/s^2)	ms			
100	(1 000)	6	Final-peak saw-tooth Half-sine Trapezoidal *	Items in secured packages transported by full cross-country vehicles Items mounted in equipment transported by or installed in full cross-country vehicles Items mounted in equipment installed in subsonic or supersonic transport aircraft Items mounted in equipment carried loose in road or rail vehicles for long periods	Severe handling shocks on road or rail transport High intensity shocks due to ignition, stage separation of rockets (space vehicles), aerodynamic buffeting and re-entry of space vehicles Portable items
500	(5 000)	1	Half-sine	Structural integrity tests on semiconductors, integrated circuits, microcircuits and micro-assemblies	Blast excited shocks, land, sea or air
1 500	(15 000)	0.5	Half-sine	Structural integrity tests on semiconductors, integrated circuits and microcircuits	

* Not primarily intended for component type specimens.

When the real operational or transportation environment is unknown the appropriate severity should be selected from Table I. Reference should also be made to Clause B3.

In determining the test severity, the specification writer should take into account the information given in relevant standards in IEC Publication 721: Classification of Environmental Conditions. Part 3: Classification of Groups of Environmental Parameters and their Severities, for example in the future IEC Publication 721-3-1: Part 3: Classification of Groups of Environmental Parameters and Their Severities – Storage, and IEC Publication 721-3-5: Part 3: Classification of Groups of Environmental Parameters and Their Severities – Ground Vehicle Installations, remembering that these publications list values of shocks encountered in practice whereas the intention of this standard is to standardize shock pulses for testing that are likely to produce the same effects as the real life shocks.

A5. **Tolerances**

The test method described in this standard is capable of a high degree of reproducibility when the tolerance requirements relating to basic pulse shape, velocity change and transverse motion are complied with.

However there are certain exceptions to these tolerance requirements and these are primarily applicable to specimens which provide a highly reactive load, that is with mass and dynamic responses which would influence the characteristics of the shock testing machine. In these cases it is expected that the relevant specification will specify relaxed tolerances or state that the values obtained shall be recorded in the test report (see Sub-clauses 4.1.1, 4.1.2 and 4.1.3).

When testing highly reactive specimens it may be necessary to carry out preliminary shock conditioning to check the characteristics of the loaded shock testing machine. With complex specimens, where only one or a limited number is provided for test, the repeated application of shock prior to the definitive test could result in an over-test and possibly unrepresentative cumulative damage. In such instances it is recommended that, whenever possible, the preliminary checking should be carried out using a representative specimen (such as rejected equipment), or, when this is not available, it may be necessary to use a weighted space model having the correct mass and centre of gravity disposition. However, it needs to be noted that a space model is unlikely to have the same dynamic response as the real specimen.

The frequency response of the overall measuring system including that of the accelerometer is an important factor in the achievement of the required pulse shape and severity and needs to be within the tolerance limits shown in Figure 4, page 20. When it is necessary to employ a low pass filter to reduce the effect of any high frequency resonances inherent in the accelerometer, the amplitude and phase characteristics of the measuring system will need to be considered in order to avoid distortion of the reproduced waveform (see Sub-clause 4.2).

For shocks of duration equal to or less than 0.5 ms, f_3 and f_4 indicated in Figure 4 may be unnecessarily high. In such instances the relevant specification should state which alternative values are to be adopted (see Sub-clause 4.2).

A6. **Velocity change** (Sub-clause 4.1.2)

For all pulse shapes the actual velocity change is specified. This velocity change may be determined in a number of ways, amongst which are:

— the impact velocity for shock pulses not involving rebound motion;

— the drop and rebound height where free fall facilities are used;

— integration of the acceleration/time curve.

When specifying integrating techniques, unless otherwise stated, the actual velocity change should be determined by integrating between the limits of 0.4*D* before the start of the pulse and 0.1*D* beyond the pulse, where *D* is the duration of the nominal pulse. It should be noted, however, that determination of the velocity change using the electronic integrating method can be difficult and may require the use of elaborate facilities. The cost implication should be considered before invoking this method.

One purpose of specifying the velocity change, and its associated tolerance, is to encourage the test laboratory to achieve a pulse equivalent to the nominal pulse, that is central within the tolerance boundaries of the pulse (see Figures 1, 2 and 3, pages 17 to 19). In this way, the reproducibility of the test is maintained.

Another purpose is associated with the shock response spectra of pulses (see Clause B3).

A7. **Conditioning** (Sub-clause 8.1)

One of the basic requirements of the test is to apply three shocks in each of six directions. When it is unnecessary to test in all six directions, for example because of symmetry or because there are clearly directions in which the effects of the shock would be less, the relevant specification may modify the number of directions, but it should not normally modify the number of shocks per direction. In practice, the number of specimens available, their complexity, cost and possible orientation, are factors which may also need to be taken into consideration.

Since it is not the intention of this test to induce fatigue in specimens, if a sufficient number of identical specimens is available they may be oriented such that the multiple axis/direction requirements of the relevant specification can be met by the application of three shocks in one direction only.

Depending on the number of identical specimens available and the mounting arrangements, particularly in the case of components, the specimens may be oriented to allow the requirements of the specification to be satisfied with a minimum number of shock applications.

For example, if six specimens are available, they may be mounted with six different orientations so that the requirements of the specification are satisfied by the application of shocks in one direction only by the shock testing machine. If three to five specimens are available, the shocks would need to be applied to the mounted components in two directions. Similarly, for two specimens, three directions would be required and for a single specimen, all six directions would be required.

When only one specimen is available, 18 shocks need to be applied but the test will then take on a somewhat different character with the possibility of it being non-representative. It is important, therefore, that the relevant specification writer give this matter adequate thought

APPENDIX B

SHOCK RESPONSE SPECTRA AND OTHER CHARACTERISTICS OF PULSE SHAPES

INTRODUCTION

In order to utilize improved techniques in shock testing and to allow for further development of shock testing machines, Test Ea requires one of three pulse shapes, with a stated severity, to be applied to the specimen fixing points and does not restrict the testing to specific machines. The choice of pulse shape and severity should be made in accordance with technical considerations appropriate to the project or type of specimen.

All methods should be regarded as acceptable from the standpoint of reproducibility of the specified test condition and for reproducing the effects of actual shock environments. In order to obtain tests which are both reproducible and which can be related to practical application, certain basic concepts have been taken into consideration in producing the test procedure for the shock test. The concepts involved are given below.

B1. **The shock response spectrum concept**

The acceleration shock response spectra of various pulse shapes have been considered when preparing the shock test procedures, because they give a useful measure of the damage potential of the shocks in many important practical cases. It must be recognized, however, that from certain points of view, they have limited applicability.

The acceleration shock response spectrum can be regarded as the maximum acceleration response to a given shock excitation of undamped mass-spring systems as a function of the resonance frequencies of the systems. The maximum acceleration of oscillatory systems determines in most cases the maximum mechanical stress of attachments and the maximum relative displacement of elastic members.

Let the framework of Figure 8, page 24, be subjected to a shock excitation with a given pulse shape, i.e. time history of the acceleration $d^2x_f/dt^2 = a(t)$. The response of the system will be oscillations with different acceleration time histories for the masses m depending on the resonance frequency (f_1, f_2, f_3, etc.).

An example of pulse shape with peak value A and duration D is shown in Figure 9a, page 25, giving response accelerations $d^2x_1/dt^2 = a_1(t)$, etc., as shown in Figure 9b, page 25

The shock response spectra (Figure 9c, page 25) result from an infinite number of resonance frequencies and are plots of the different extreme acceleration responses a_{max} in Figure 9b as functions of resonance frequency for the undamped linear mass-spring system.

The positive initial shock spectrum, +I, in Figure 9c is the plot of the maximum response occurring during the pulse duration in the same direction as the exciting pulse: the $a_{max}(+I)$ in Figure 9b.

The positive residual shock spectrum, +R, is the plot of the same maximum response occurring after the pulse duration and in the same direction as the pulse: the $a_{max}(+R)$.

The negative initial shock spectrum, –I, is the plot of the maximum response during the pulse in the opposite direction to the exciting pulse: the $a_{max}(-I)$.

The negative residual shock spectrum, –R, is the plot of the maximum response after the pulse in the opposite direction to the pulse: $a_{max}(-R)$.

All four spectra are shown in Figure 9c with the examples of resonance frequencies of the framework also noted.

As the damping is assumed to be zero, the response after the pulse duration is a steady sinusoidal oscillation around zero acceleration. Thus, the positive residual and negative residual are images in the frequency axis of each other. Usually, only the positive residual is shown in presenting acceleration response spectra.

The negative initial spectrum is everywhere less in magnitude than the positive initial spectrum for the pulse shapes of concern here. The shock testing procedure therefore requires testing in both directions along each axis. The maximum acceleration for the parts will then be determined by the positive initial spectrum in both directions. The negative initial spectrum is therefore omitted in the following.

The envelope of the positive initial and positive residual spectra shows the maximum response acceleration of the masses whenever it occurs. It is called the "maximax" shock response spectrum. However, in order to convey the requisite information clearly the initial and residual spectra are plotted separately. In practice, it is often difficult to find the precise pulse duration, and in such cases, it is impracticable to determine these spectra individually.

The spectra can easily be generalized with respect to peak value and duration for all shocks with the same pulse shape. If, instead of f and a_{max}, the co-ordinate scales fD and a_{max}/A are chosen, the shock spectra will be valid for any shocks of the same pulse shape. The spectra given here have therefore two co-ordinate scales: a_{max}/A as a function of fD and a_{max} as a function of f for a particular example of duration and peak acceleration.

B2. The use of first order shock response spectra in practical cases

In components and equipments, the internal parts generally form more complicated systems than undamped systems, for instance series-connected multi-degree-of-freedom systems with damping, as shown in Figure 10, page 26. In this case, shock-excited oscillations in one outer system may cause damage to an inner system by coupled resonance effects. These effects can be described by sets of higher order shock spectra, valid for given combinations of resonance frequencies of the mass-spring sub-systems.

If the resonance frequencies of the series-connected systems are separated to any significant extent, the first order shock spectrum gives a reasonable measure for comparing the damage potential of shocks of different pulse shapes.

The highest acceleration of the internal masses will be reached when resonances are excited during the period of the pulse. In this case, the oscillation acceleration will be superimposed upon that of the pulse itself. Hence, it will be evident from Clause B3 that the greatest liability to damage in this respect will be when using short rise time pulses.

In general, damping will decrease the response at medium frequencies during the pulse and at both medium and higher frequencies after the pulse. The damping will decrease both the amplitude and the duration of oscillation and attenuates thereby the response of any inner system. The damage potential of a shock is therefore in general lower for damped systems than for undamped, particularly for multi-degree-of-freedom systems. The shock response spectra of undamped systems represent the worst possible cases.

Acceleration shock response spectra therefore do not describe completely the damage potential of the shock. Nevertheless, this simplified presentation is sufficient to allow an appropriate pulse shape to be chosen for actual configurations.

Before comparing shock response spectra, accurate shock testing requires a judgement of the importance of prolonged response oscillations represented by the residual spectra, compared with the short responses represented by the initial spectra. The judgement should be based on possible failure modes.

B3. The shock response spectra of the nominal pulse shapes

The acceleration shock response spectra of the recommended nominal pulse shapes are shown in Figures 5, 6 and 7, pages 21 to 23.

The form of the spectra for the same pulse shape is the same irrespective of pulse duration due to the use of non-dimensional scales. The normalized frequency scale fD allows frequency scales for any duration D to be determined. The generalized response scale, a_{max}/A, allows the determination of acceleration scales for any peak value A.

At low frequencies and for $fD < 0.2$, the initial spectra are nearly the same, while the residual spectra are nearly proportional to the velocity change of the pulse. This is one reason for the additional tolerance requirement on velocity change. The trapezoidal pulse shape has the highest velocity change for a given peak acceleration and duration.

In the intermediate frequency range $0.2 \leqslant fD \leqslant 10$, the initial spectra show differences in level depending mainly on the rise time of the pulse. The final-peak saw-tooth pulse has the longest rise time and shows the lowest response for a given value. The trapezoidal pulse shows the highest response for a given peak acceleration value due to the short rise time and the flatness of the peak, allowing even the low-frequency oscillations to reach their peak before the instantaneous value of the originating pulse falls. The residual spectrum of the saw-tooth pulse also shows a relatively high and smooth course up to the first zero at approximately $fD = 10$. The frequency of this zero depends on the ratio of the rise and fall times, the frequency increasing for steeper fall of the final peak. The residual spectra of the half-sine and trapezoidal pulses have repeated zeros beginning at relatively low frequencies. approximately $fD = 1$. This is due to the symmetry of these pulses and is a great disadvantage from the point of view of reproducibility of the tests. Slight changes in pulse duration or symmetry may cause considerable changes in residual response and give different test results.

At higher frequencies, the initial spectra approach $a_{max}/A = 1$ and the residual spectra zero. This is illustrated by the fact that a mass on a very stiff spring follows closely the acceleration-time history of the exciting pulse. The statement is valid for all pulse shapes having finite rise and fall times.

B4. The effect of ripple

Oscillatory systems with low or no damping are very sensitive to ripple on the pulse. As an example, the effect on the shock spectrum of a half-sine pulse is shown in Figure 11, page 27.

A 460 Hz signal of 50 m/s^2 (5 g_n) amplitude is superimposed on the nominal 500 m/s^2 (50 g_n) and 11 ms half-sine pulse (10% ripple, $Q = 5$). After the nominal pulse a damping ratio of 10% is applied to the ripple. This produces a theoretical pulse comparable with the actual pulses which may be obtained by shock generators. The effect as can be seen is considerable, especially on the residual spectrum. An increase of the ripple to 20% would increase the peak values to around $a_{max}/A = 4$. In general, ripple should therefore be avoided as far as possible in order to preserve reproducibility of the test.

Ripple frequencies in the low frequency range (where $fD < 0.2$) have a negligible effect. Frequencies in the higher ranges (where $fD \geqslant 0.2$) give peaks at the ripple frequency, the response increasing with higher frequencies for a constant ripple amplitude. The residual spectrum is always relatively more affected than the initial. The initial spectrum of the pulse shape with short rise time, the trapezoidal, is sensitive only to high-frequency ripple. The initial spectrum of the final-peak saw-tooth is very sensitive to ripple in the whole intermediate and high frequency range.

Ripple which is only slightly damped and therefore extends for an appreciable time after the end of the nominal pulse can affect the residual spectrum considerably.

When excessive ripple is present, the results of a shock test could be significantly different from those obtained in a test where ripple is within the specified tolerance bands. The tolerance bands around the nominal pulse shapes are intended to take care of permitted ripple as well as other shape distortions.

B5. Reproducing the effects of various shock pulses by a single pulse

The recommended shock pulses are not intended to simulate the shocks encountered in practice, but to reproduce the effects of the real environment. For shock testing, therefore, consideration of the shock spectra of the real environment is necessary. However, this information is often limited to a statistical distribution of peak acceleration or to an estimation of design level.

It is often possible to reproduce with a single pulse the effects of a number of shocks of given peak value and varying duration.

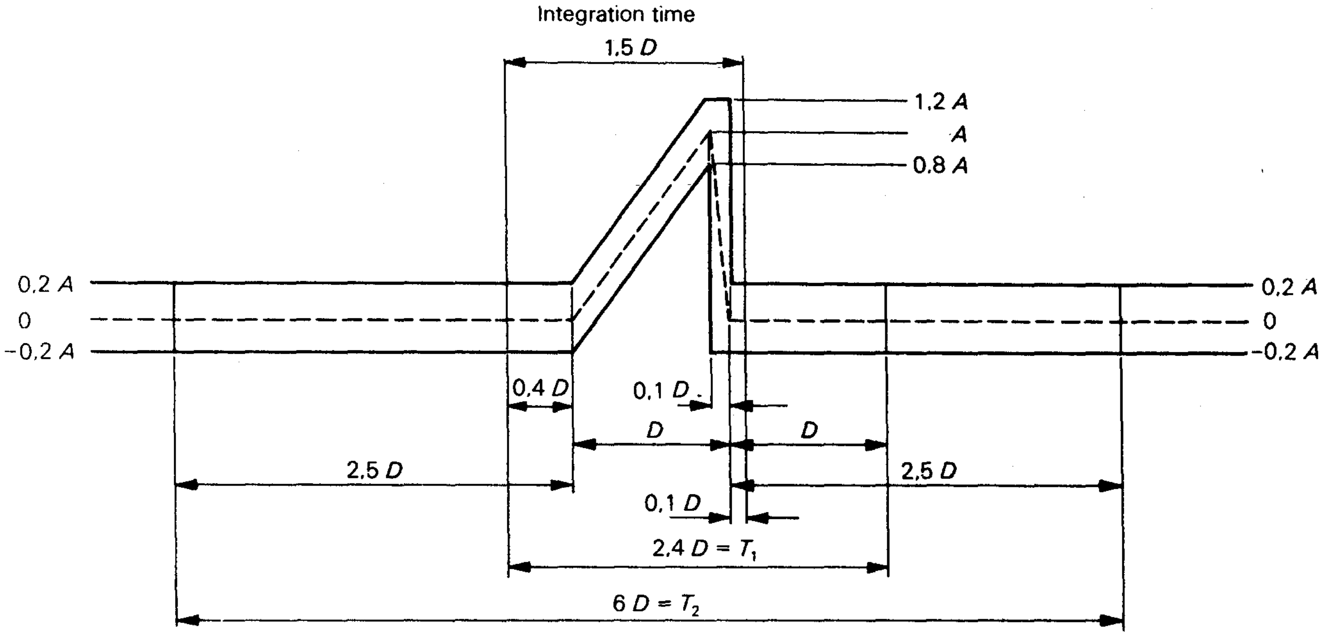
Figure 12, page 28, provides a comparison of the response spectra of a series of half-sine pulses with the response spectrum of a single saw-tooth waveform of higher peak value. Although there is some overtesting with regard to the initial spectrum there is a considerable degree of overlap of these spectra.

APPENDIX C

COMPARISON BETWEEN IMPACT TESTS

Test Ea and guidance: Shock (I E C Publication 68-2-27)	— is intended to reproduce the effects of non-repetitive shocks likely to be encountered by components and equipment in service and during transportation.
Test Eb and guidance: Bump (I E C Publication 68-2-29)	— is intended to reproduce the effects of repetitive shocks likely to be experienced by components and equipment during transportation or when installed in various classes of vehicles.
Test Ec: Drop and topple, primarily for equipment-type specimens (I E C Publication 68-2-31)	— is a simple test intended to assess the effects of knocks or jolts likely to be received primarily by equipment-type specimens during repair work or rough handling on a table or bench.
Test Ed: Free fall (I E C Publication 68-2-32) Procedure 1 — Free fall	— is a simple test intended to assess the effects of falls likely to be experienced due to rough handling. It is also suitable for demonstrating a degree of robustness.
Test Ed: Free fall (I E C Publication 68-2-32) Procedure 2 — Free fall repeated	— is intended to reproduce the effects of repetitive shocks likely to be received by certain component type specimens, for example connectors in service.
Test Ee and guidance: Bounce (I E C Publication 68-2-XX) (In preparation)	— is intended to reproduce the effects of the random shock conditions experienced by specimens which may be carried as loose cargo in wheeled vehicles travelling over irregular surfaces.

Shock and bump tests are performed on the specimen when fixed to the shock testing machine. Drop and topple, free fall, repeated free fall and bounce tests are performed with the specimen free.



------ nominal pulse

—— limits of tolerance

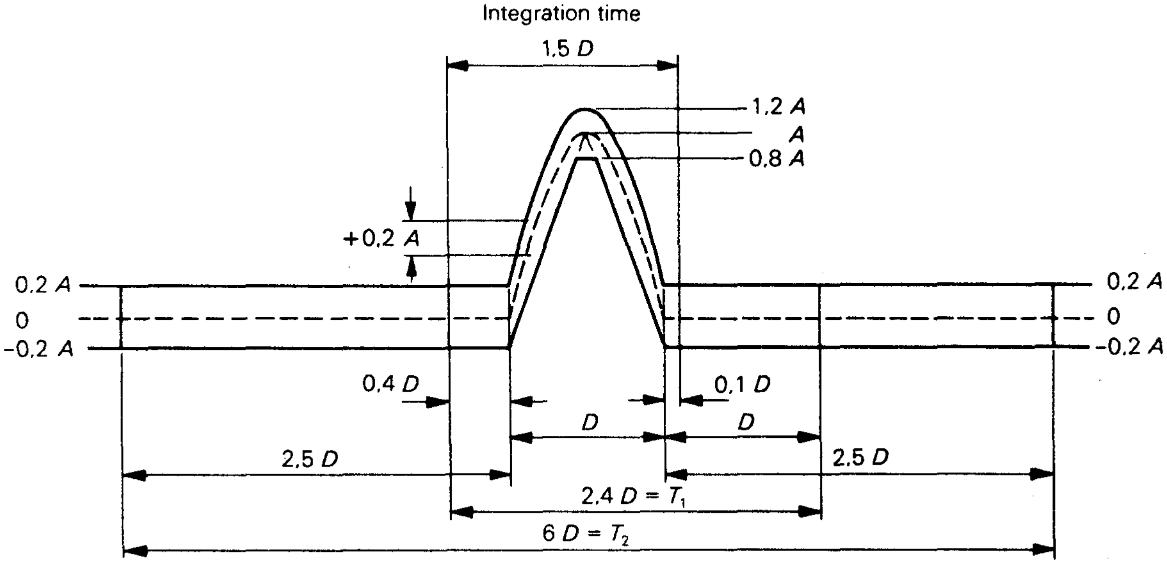
D = duration of nominal pulse

A = peak acceleration of nominal pulse

T_1 = minimum time during which the pulse shall be monitored for shocks produced using a conventional shock testing machine

T_2 = minimum time during which the pulse shall be monitored for shocks produced using a vibration generator

FIG. 1. — Final-peak saw-tooth pulse.



------ nominal pulse

—— limits of tolerance

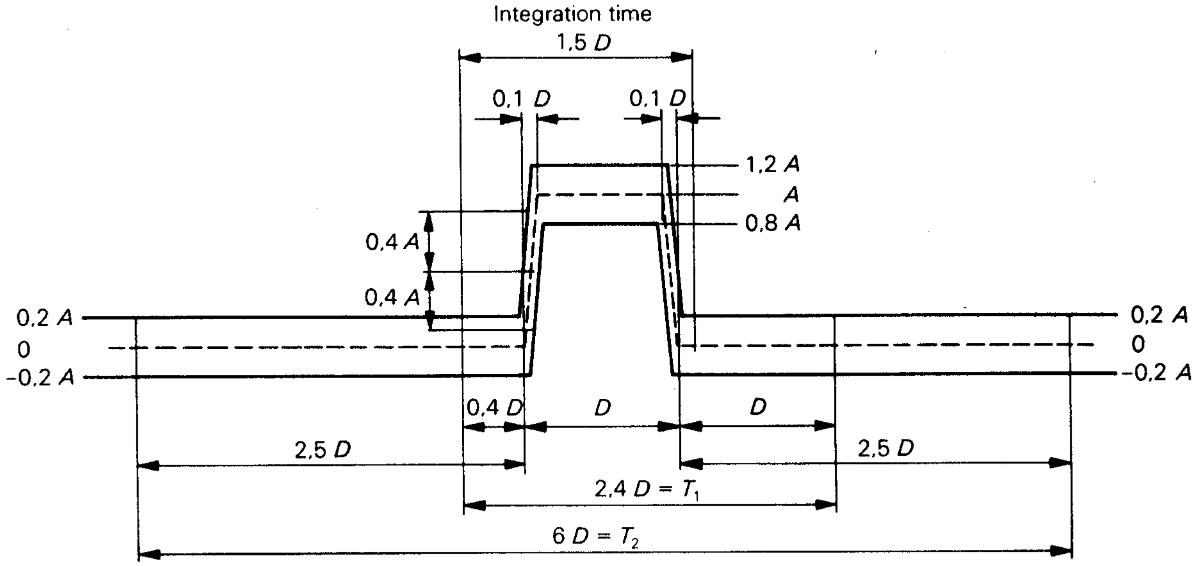
D = duration of nominal pulse

A = peak acceleration of nominal pulse

T_1 = minimum time during which the pulse shall be monitored for shocks produced using a conventional shock testing machine

T_2 = minimum time during which the pulse shall be monitored for shocks produced using a vibration generator

FIG. 2. — Half-sine pulse.



------ nominal pulse

—— limits of tolerance

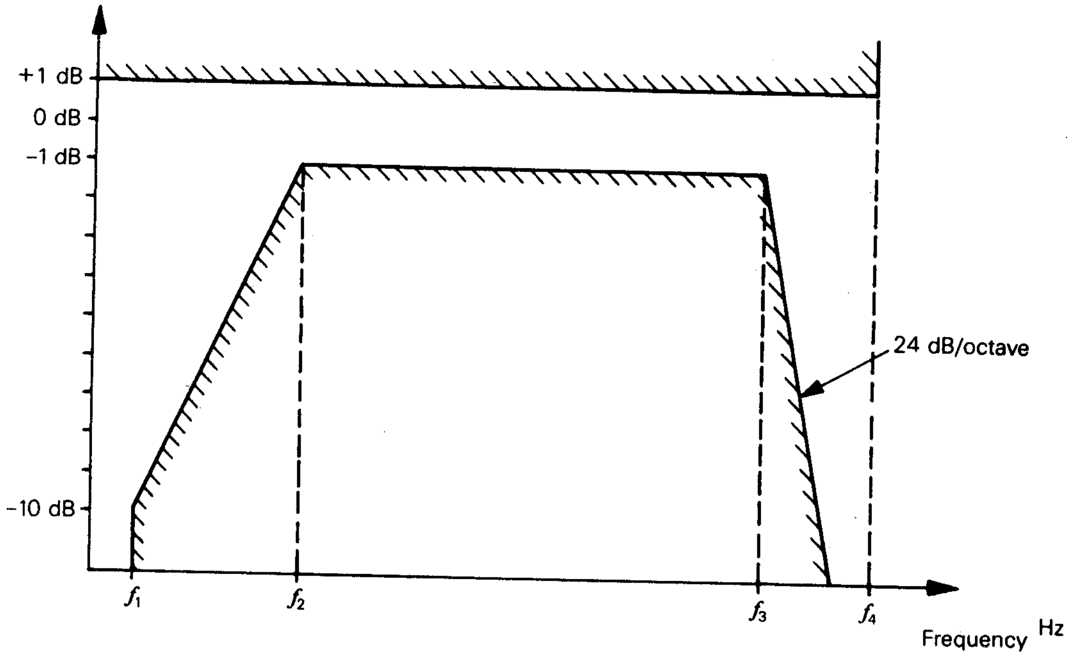
D = duration of nominal pulse

A = peak acceleration of nominal pulse

T_1 = minimum time during which the pulse shall be monitored for shocks produced using a conventional shock testing machine

T_2 = minimum time during which the pulse shall be monitored for shocks produced using a vibration generator

FIG. 3. — Trapezoidal pulse.



Duration of pulse (ms)	Low-frequency cut-off (Hz)		High frequency cut-off (kHz)	Frequency beyond which the response may rise above +1 dB (kHz)
	f_1	f_2	f_3	f_4
0,2	20	120	20	40
0,5	10	50	15	30
1	4	20	10	20
3	2	10	5	10
6	1	4	2	4
11	0,5	2	1	2
18 et/and 30	0,2	1	1	2

Note. —

For shocks of duration equal to or less than 0.5 ms, the values of f_3 and f_4 indicated in this figure may be unnecessarily high. In such instances the relevant specification should state which alternative values are to be adopted.

FIG. 4. —

Frequency characteristics of the measuring system.

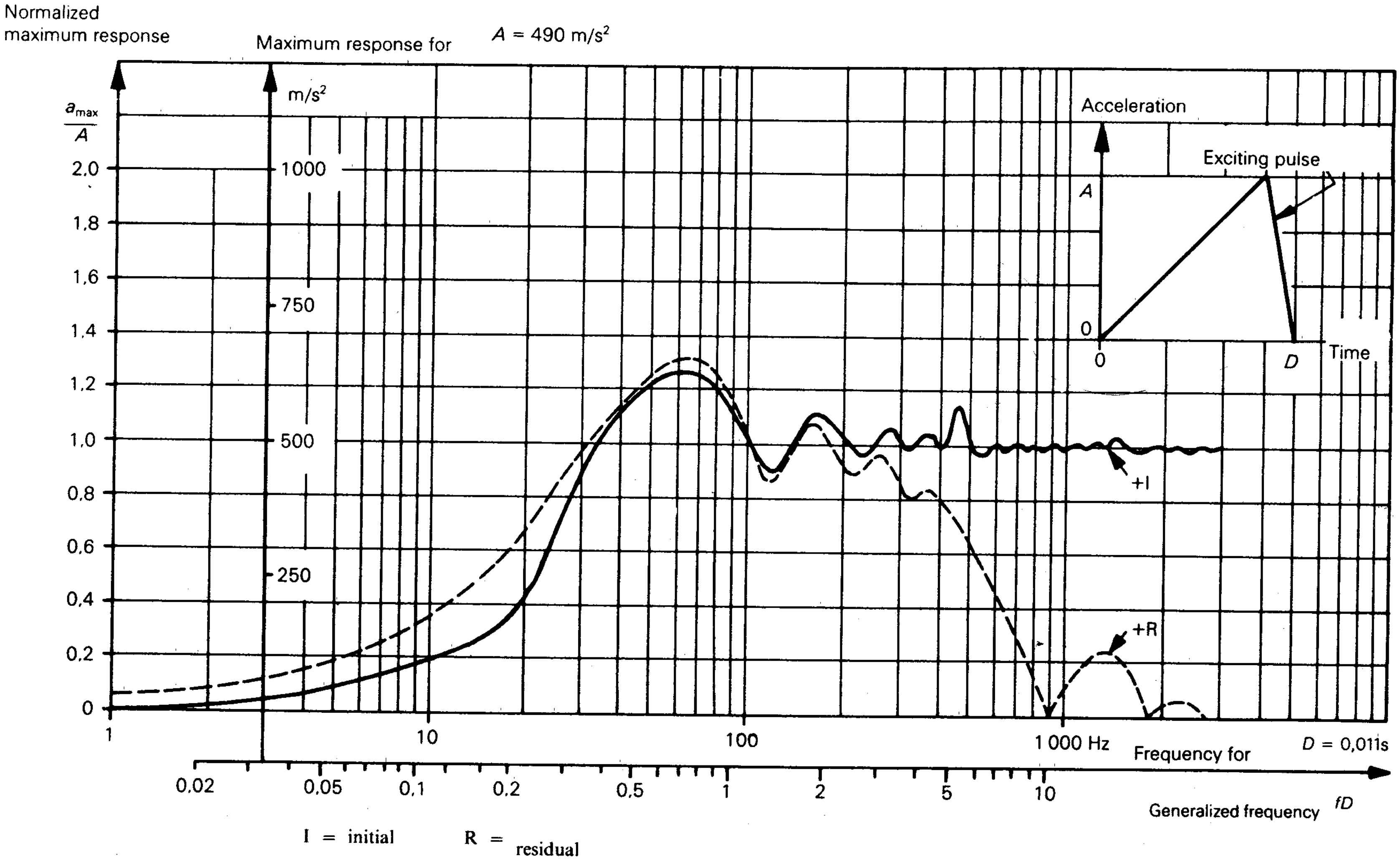
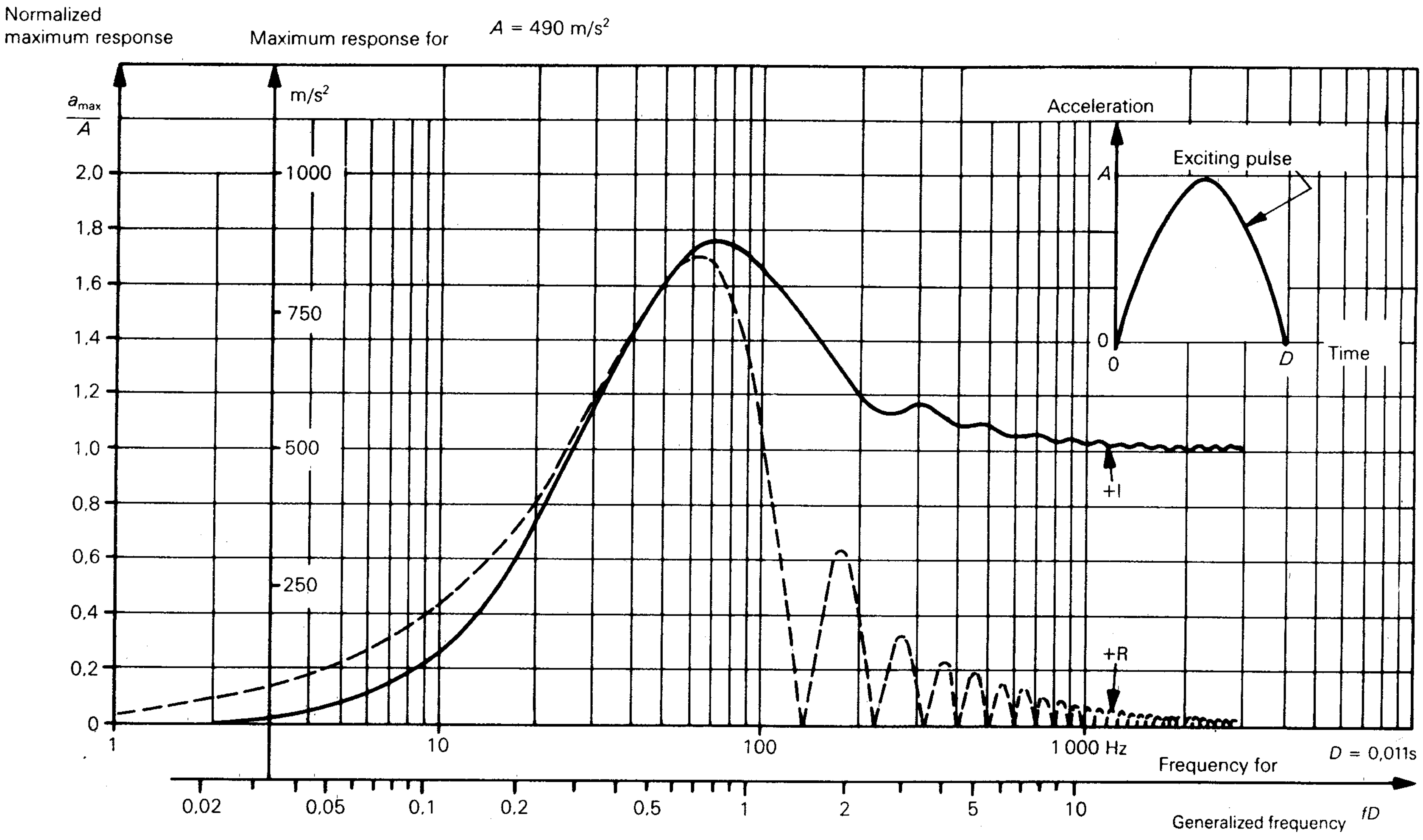


FIG. 5. —

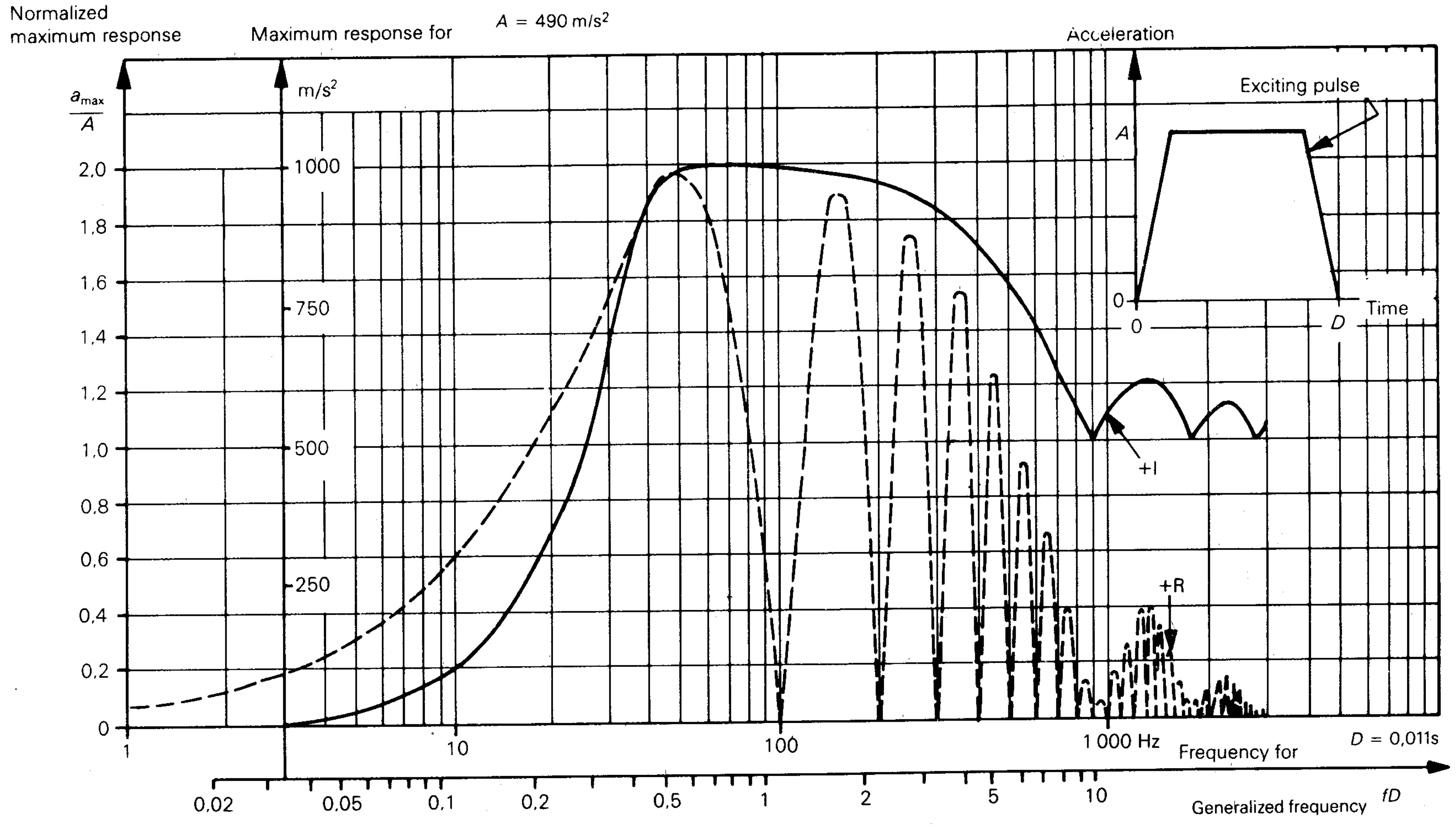
Shock response spectrum of a final-peak saw-tooth pulse.



I = initial R = residual

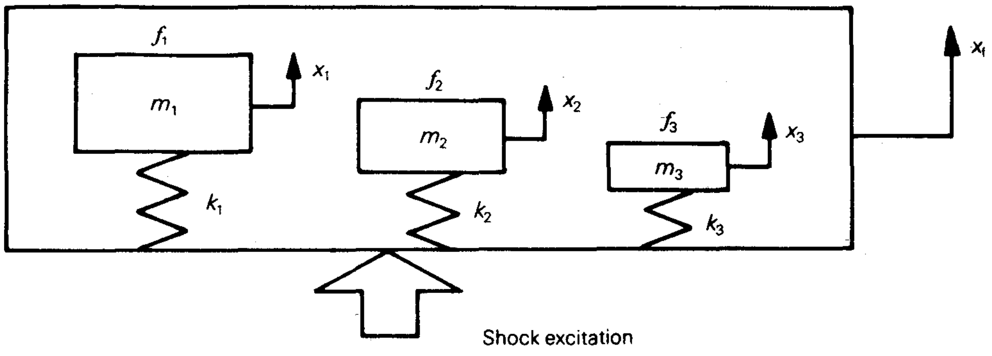
FIG. 6. —

Shock response spectrum of a symmetrical half-sine pulse.



I = initial R = residual

FIG. 7. — Shock response spectrum of a symmetrical trapezoidal pulse.



m = mass

k = spring constant

x = displacement relative to a fixed co-ordinate system

FIG. 8. —

Framework or box containing oscillatory systems of which f_1, f_2 and f_3 are examples of resonance frequencies.

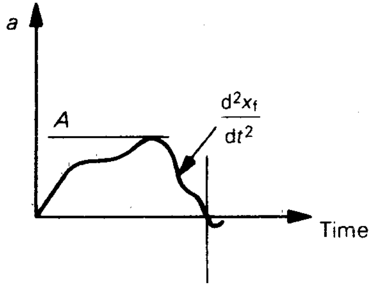


FIG. 9a. — Exciting pulse.

a = acceleration

A = peak acceleration value of the exciting pulse

D = duration of the exciting pulse

a_{max} = extreme values of response acceleration

+I = positive initial −I = negative initial

+R = positive residual −R = negative residual

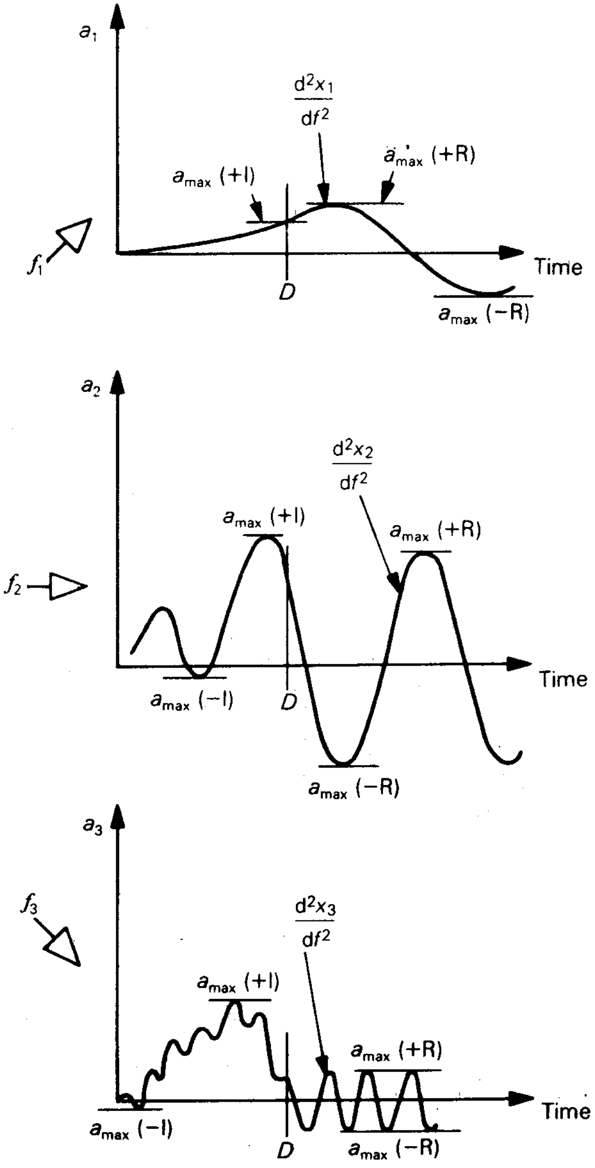


FIG. 9b. — Responses for f_1, f_2 and f_3.

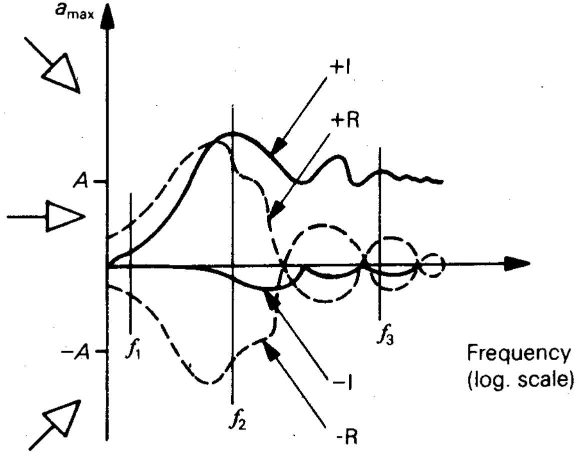


FIG. 9c. — Spectra which result from an infinite number of frequencies, with f_1, f_2 and f_3 shown as finite points on the continuous curves.

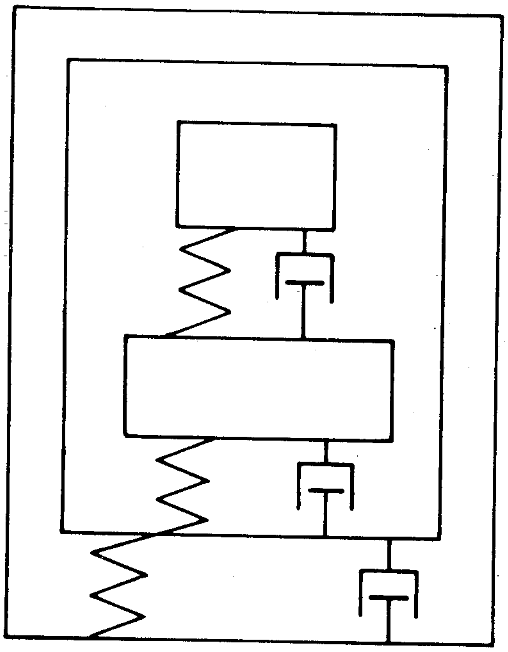
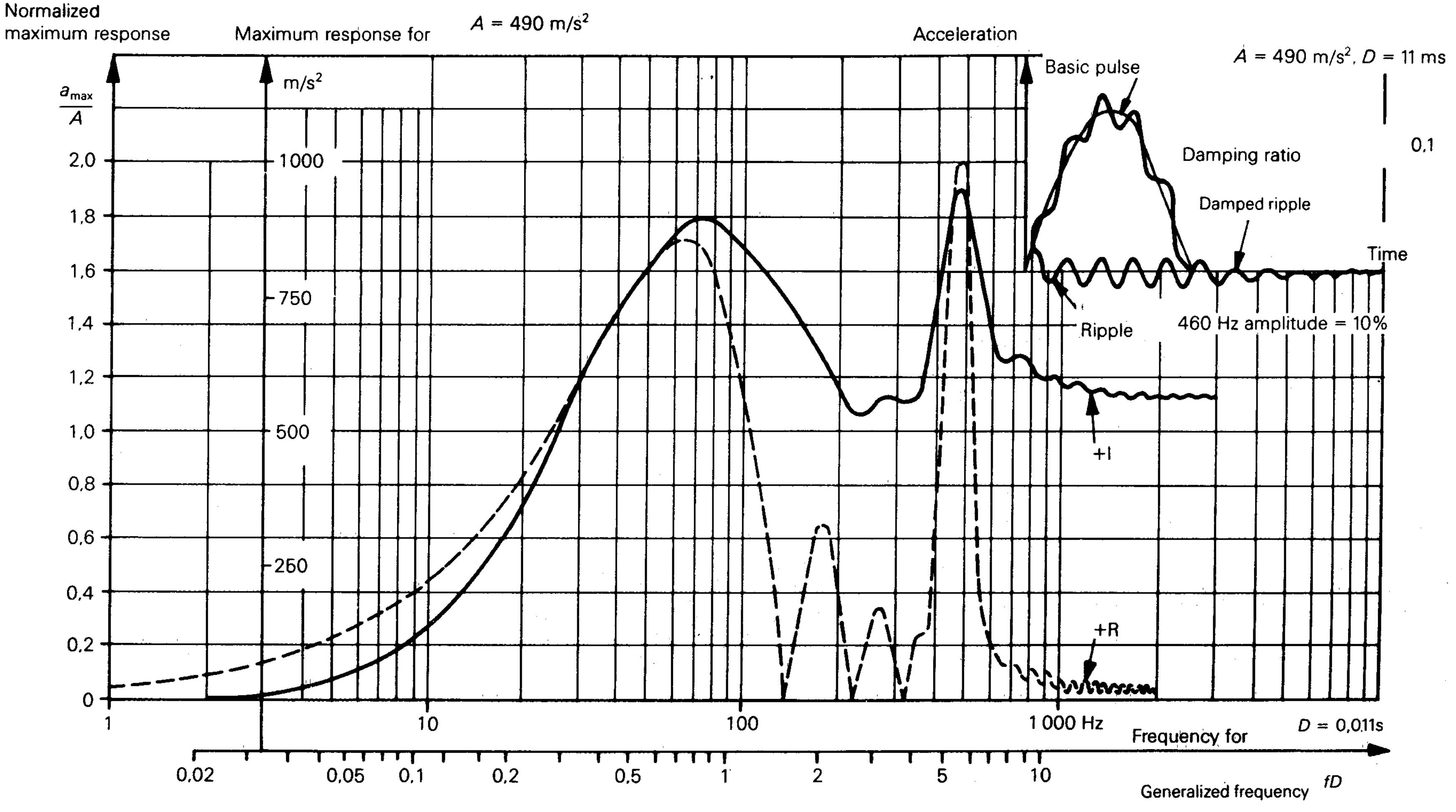
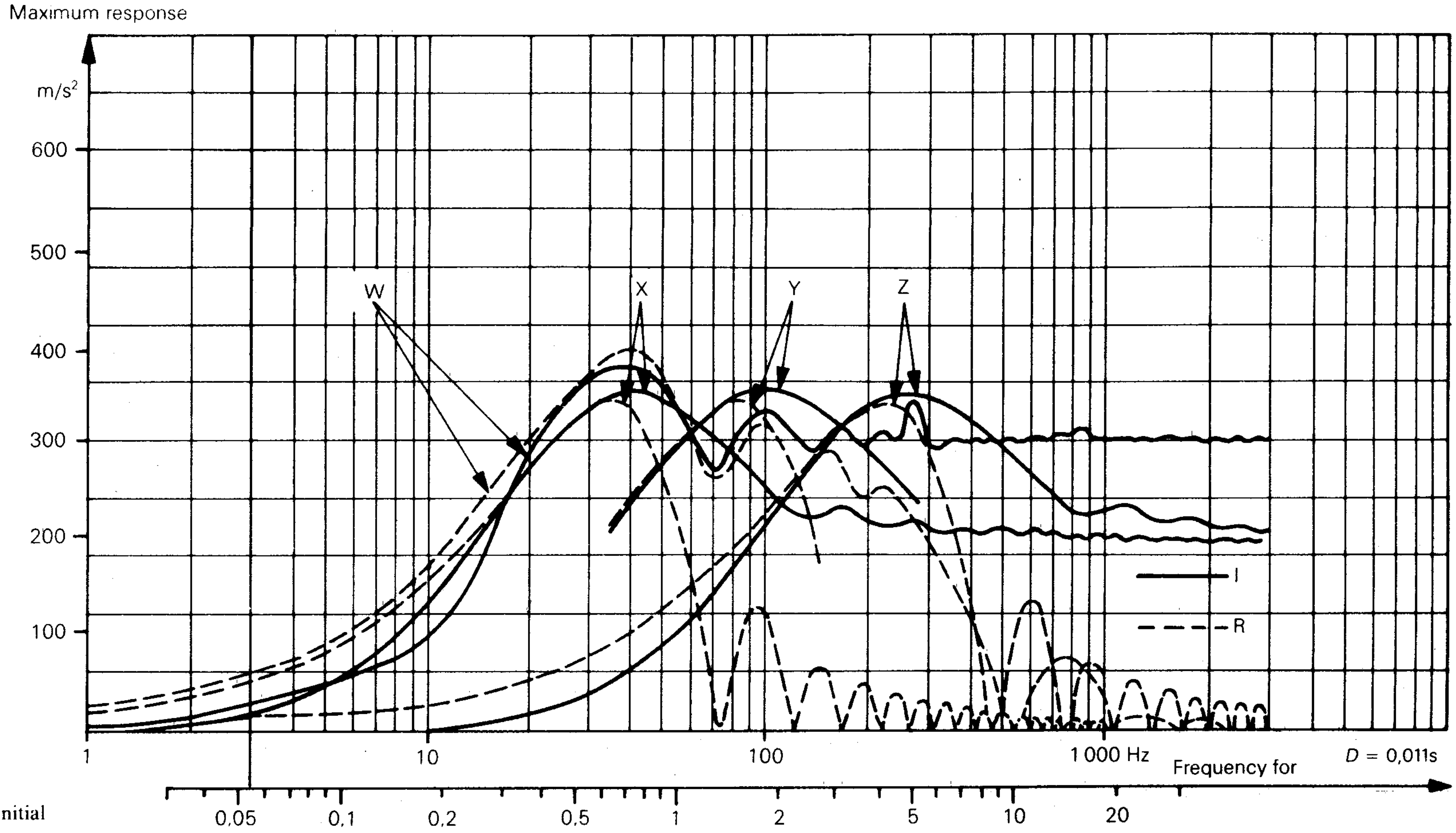


FIG. 10. — Framework containing damped multi-degree-of-freedom system.



I = initial R = residual

FIG. 11. — Shock response spectrum of a half-sine pulse with ripple.



I = initial

R = residual

W = final-peak saw-tooth 300 m/s², 18 ms

X = half-sine 200 m/s², 20 ms

Y = half-sine 200 m/s², 8 ms

Z = half-sine 200 m/s², 3 ms

FIG. 12. — Spectrum of a final-peak saw-tooth 300 m/s², 18 ms pulse compared with the spectra of 200 m/s² half-sine pulses with durations between 3 ms and 20 ms.

(*Continued from second cover*)

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60068-2-55 (1987) Basic environmental testing procedures — Part 2 : Tests — Test Ee and guidance : Bounce	IS 9000 (Part 7/Sec 6) : 1988 Basic environmental testing procedures for electronic and electrical items: Part 7 Impact test, Section 6 Test Ee : Bounce	Technically Equivalent
IEC 60721-3 (1984) Classification of environmental conditions — Part 3 : Classification of groups of environmental parameters and their severities	IS 13736 (Part 3/Sec 0) : 1993 Classification of environmental conditions: Part 3 Classification of groups of environmental parameters and their severities, Section 0 Introduction	Identical
IEC 60721-3-1 (1987) Classification of environmental conditions — Part 3 : Classification of groups of environmental parameters and their severities — Storage	IS 13736 (Part 3/Sec 1) : 1993 Classification of environmental condition: Part 3 Classification of groups of environmental parameters and their severities, Section 1 Storage	do
IEC 60721-3-5 (1985) Classification of environmental conditions — Part 3 : Classification of groups of environmental parameters and their severities — Ground vehicle Installations	IS 13736 (Part 3/Sec 5) : 1993 Classification of environmental condition: Part 3 Classification of groups of environmental parameters and their severities, Section 5 Ground vehicle installations	do
ISO 2041 : 1975 Vibration and shock — Vocabulary	IS 11717 : 2000 Vocabulary on vibration and shock (*first revision*)	do

Only the English language text in the International Standard has been retained while adopting it in this Indian Standard, and as such the page numbers given here are not the same as in IEC Publication.

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This Indian Standard has been developed from Doc: No. LTD 02 (09).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Printed at Simco Printing Press, Delhi